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14. ABSTRACT
Anti-reflective (AR) coatings comprised of several layers of oxide and nitride dielectric materials have successfully been sputter deposited on UV transparent polymethylmethacrylate (UVT-PMMA) windows. The amorphous coatings are deposited using reactive sputtering in a custom-designed magnetron sputtering tool. The AR coatings are adherent, radiation hard, and improve the transmission of UVT-PMMA windows by approximately 5% in the 300-450 nm range. The coatings will be applied and tested on UVT-PMMA Fresnel lenses for use in space-borne telescopes.

15. SUBJECT TERMS
Anti-reflective coatings, Fresnel lens, polymethylmethacrylate, PMMA

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Multilayer Anti-Reflective Coating Development for PMMA Fresnel Lenses

Don Patterson, Keith Jamison, and Byron Zollars

Mirror Technology SBIR/STTR Workshop

Boulder, CO

June 7, 2009

Radiation Hard Multilayer Optical Coatings

SBIR Phase II Contract

NNX09CB36C

COTR: Bill Jones

Marshall Space Flight Center

NanΩhmics

Space ready multi-layer optical coatings

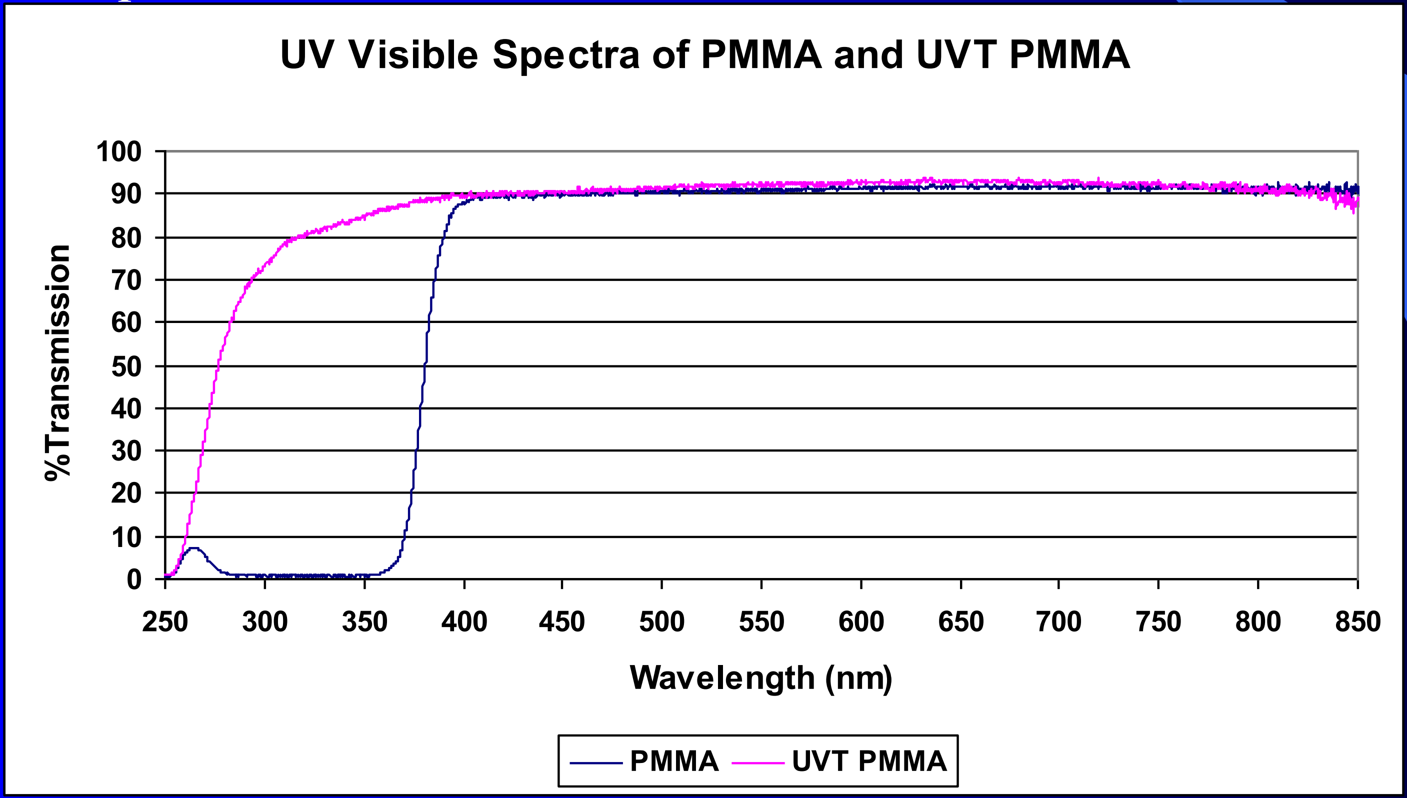
Problem: New optical coatings need to be developed for next generation light weight space base optics for use in programs such as NASA’s EUSO observatory

Phase II Goal: Develop a robust anti-reflective coating that can be applied to UVT-PMMA Fresnel lenses

Nanohmics’ Approach: Multi-layer amorphous nitrides / oxides as optical coating

Why PMMA?

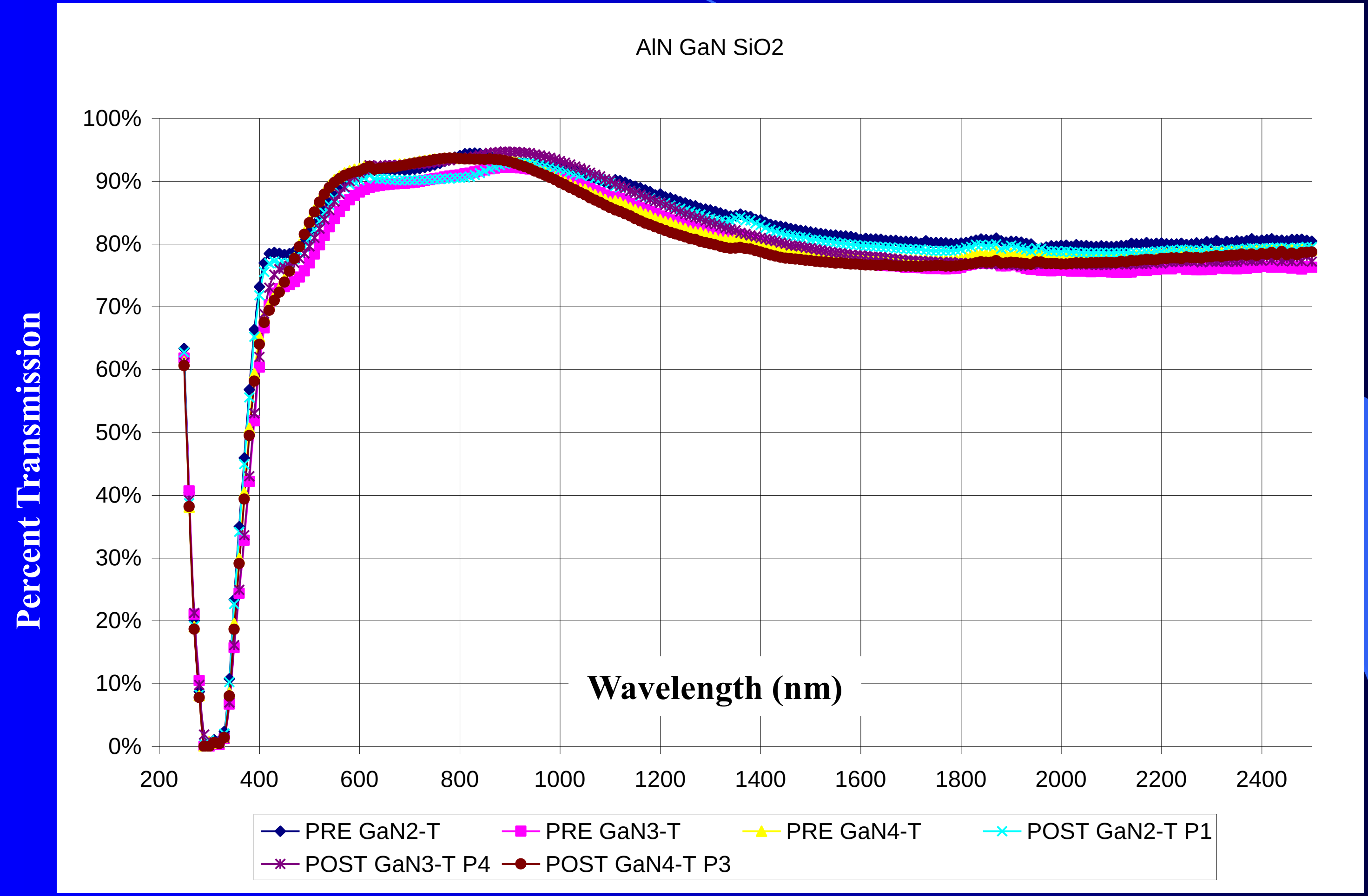
- Light weight
- UV Resistant
- UV Transparent
- Inexpensive



Advantages of Amorphous Oxides and Nitrides

- Proven radiation resistance to darkening
- Can be used to design anti-reflection, reflective, and band pass coatings
- Room temperature deposition
- Adhere well to most materials
- Robust coating

Radiation Hardness

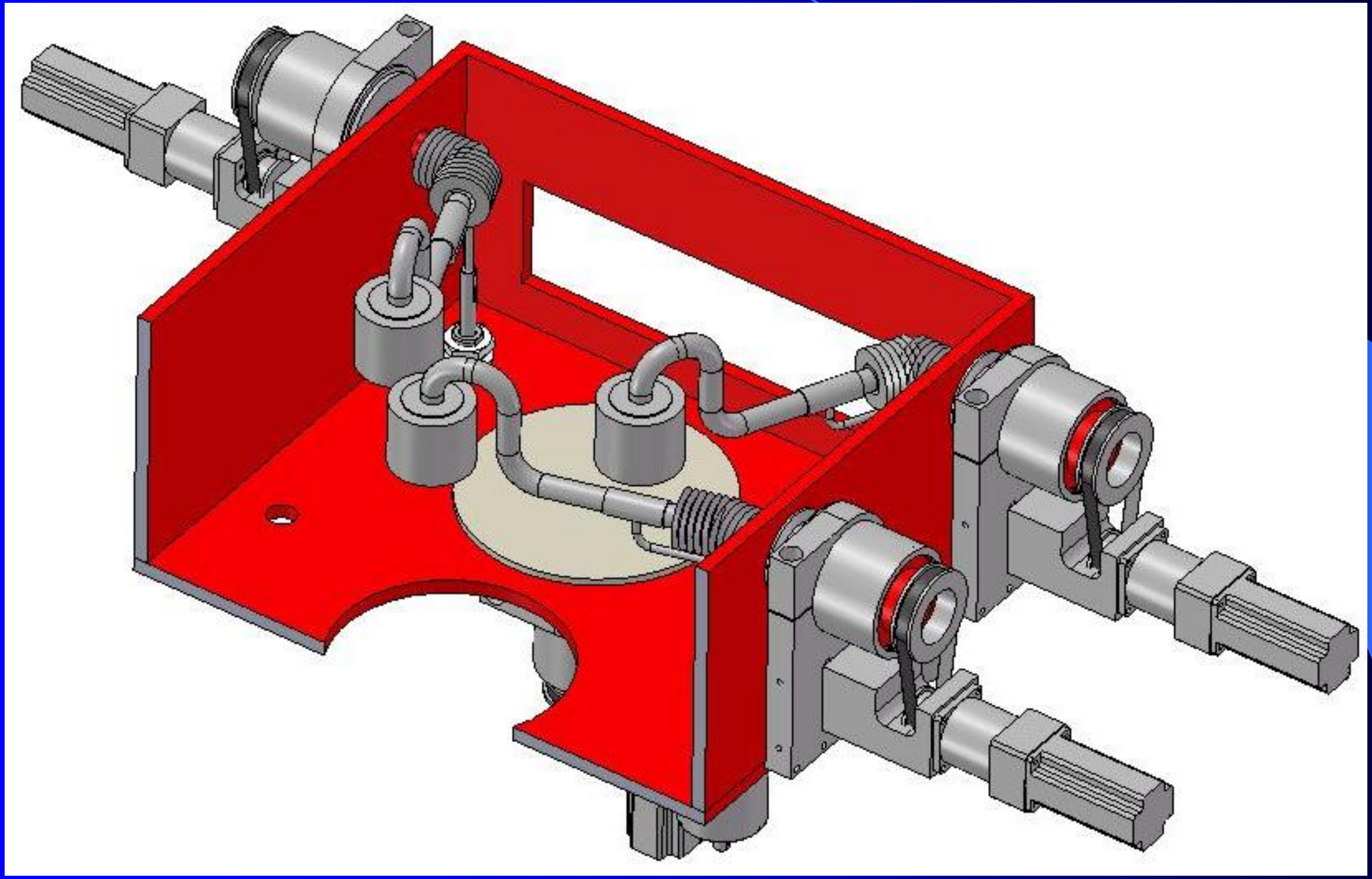


Multi-layer nitride / oxide coating exposed to ~ 10^{15} protons/cc flux at 20 keV, 50 keV, 100 keV and 300 keV

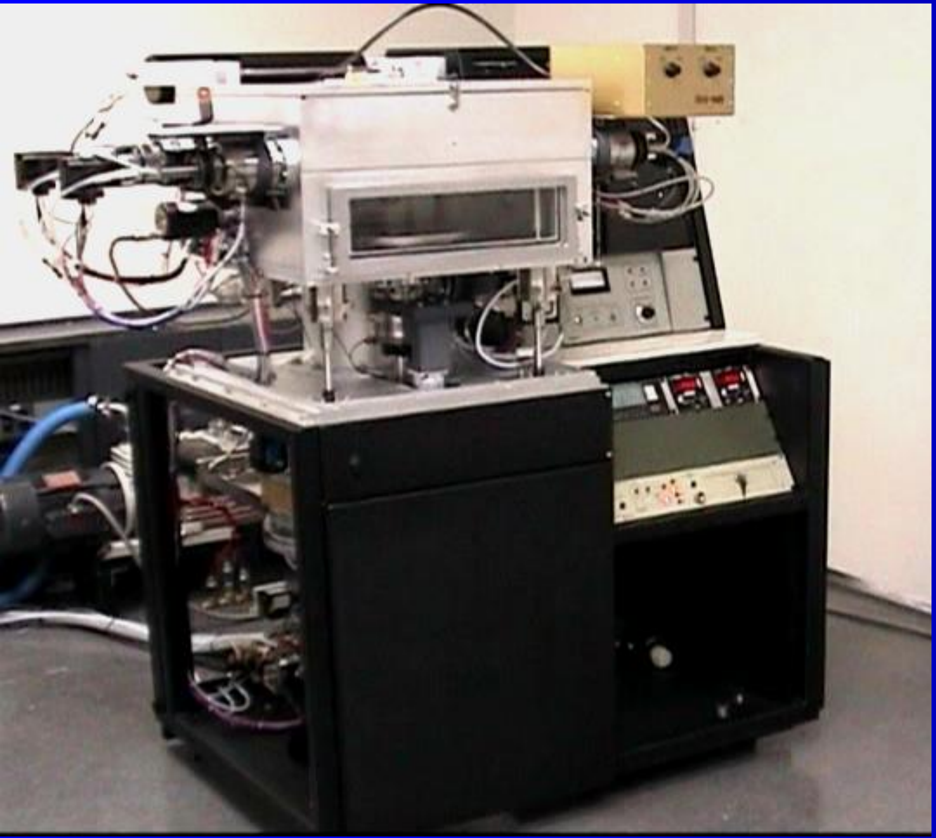
Advantages of Sputter Deposition

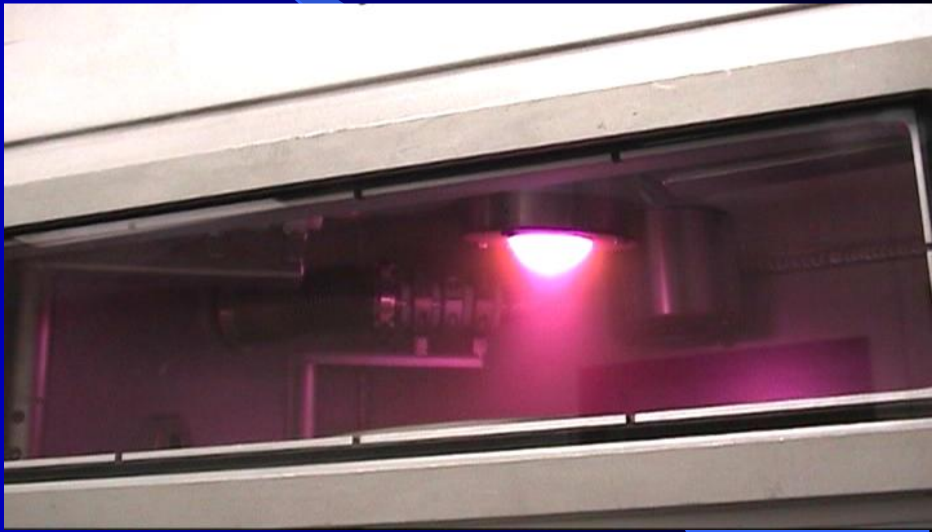
- Able to deposit optical quality films
- Reactive growth of nitrides and oxides results in relatively fast deposition rates
- Sputter process results in higher density, better adhesion coatings compared to e-beam deposition
  - Bias sample if increased density desired
- Deposit on cooled substrates
- Large established infrastructure
- Relatively inexpensive process that can handle large substrates (12” dia. in our system)

New Deposition System



Sputter Deposition System





Amorphous Nitride / Oxide Growth

- Coating materials: AlN, ZrO_2, and SiO_2
- All materials grown using reactive sputtering
  - Solid target (Al, Zr, Si)
  - Background gas ($Ar:O_2$ or $Ar:N_2$)
- RF power = 200 W
- Growth rates ~1.7-7.7 nm/min
- Thickness measured using optical methods (Filmetrics F20) and profilometry (Dektak)
- No delamination noted after thermal cycling (-55 C to 75 C)

Growth Rate and Adhesion Strength

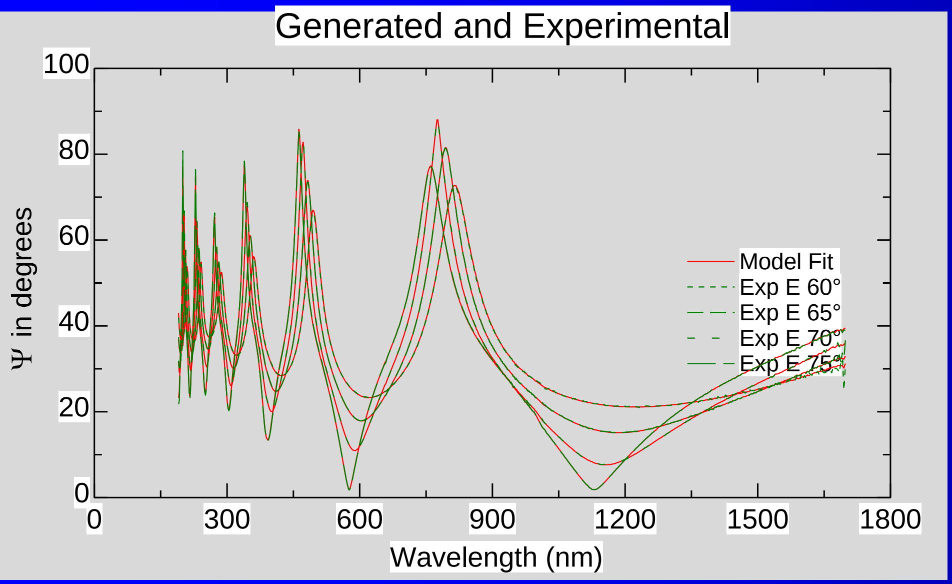
Growth rate of SiO_2, AlN, and ZrO_2 at 200 W RF power.

Material	Growth Rate
SiO_2	7.7 nm/min
AlN	2.4 nm/min
ZrO_2	1.7 nm/min

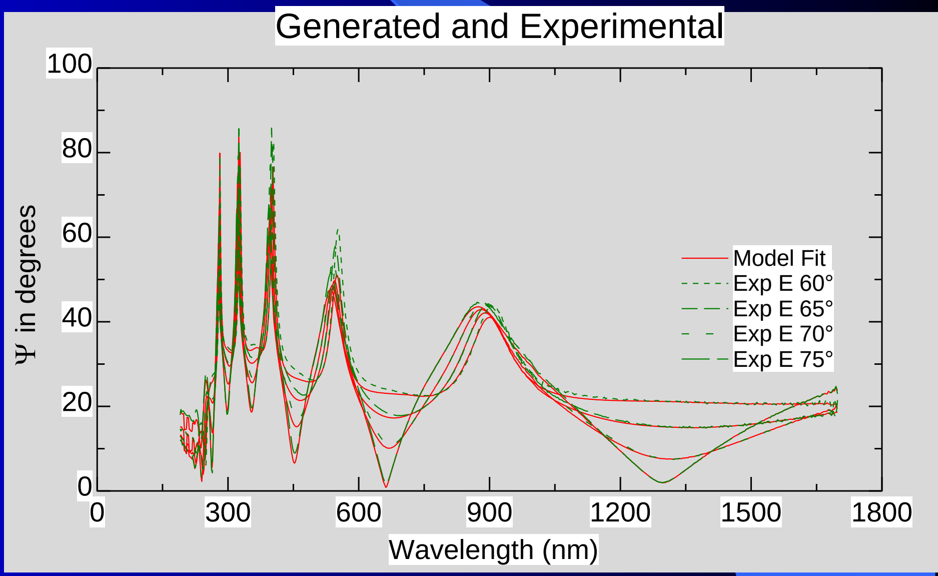
Adhesion strength to PMMA

	AlN	SiO_2	ZrO_2
Max Adhesion Force (Kg)	4.7	3.0	1.0
Max Adhesion Strength (Kg/cm^2)	83	52	18

Optical Constant Data



SiO_2

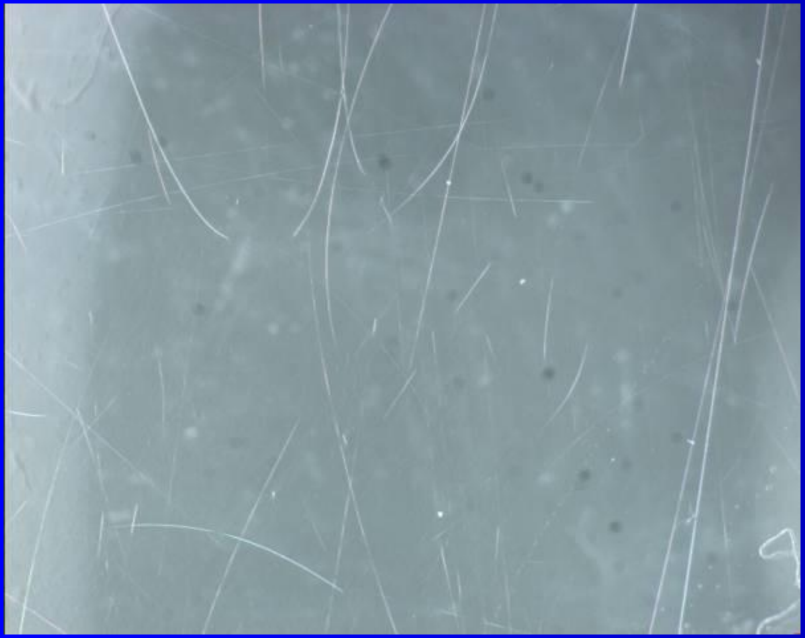


AlN

- At 500 nm:
  - AlN (n=1.973, k=0.0004)
  - ZrO_2 (n=2.10, k=0.0002)
  - SiO_2 (n=1.47, k=0.0007)

Stress

AR Coatings at 200 W; 500x magnification

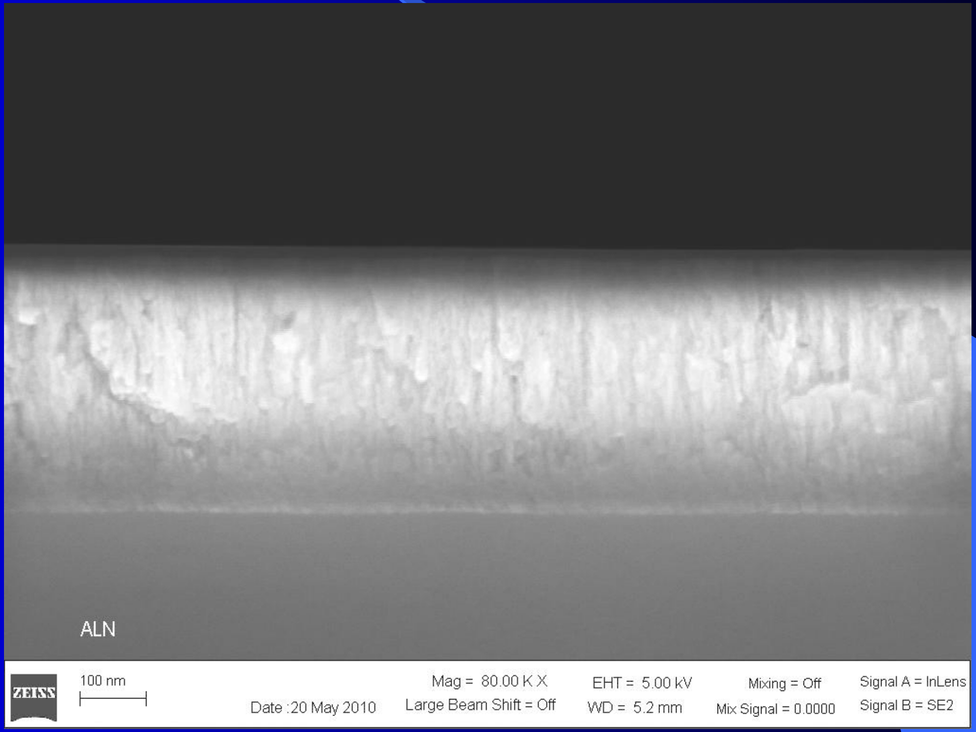


Old System

New System

Amorphous Films

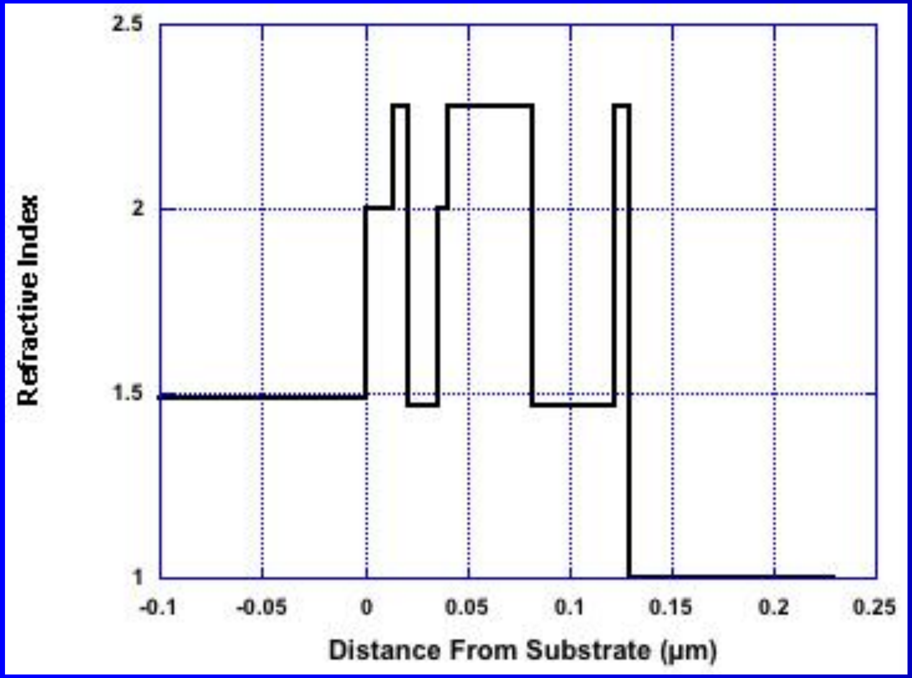
Old System



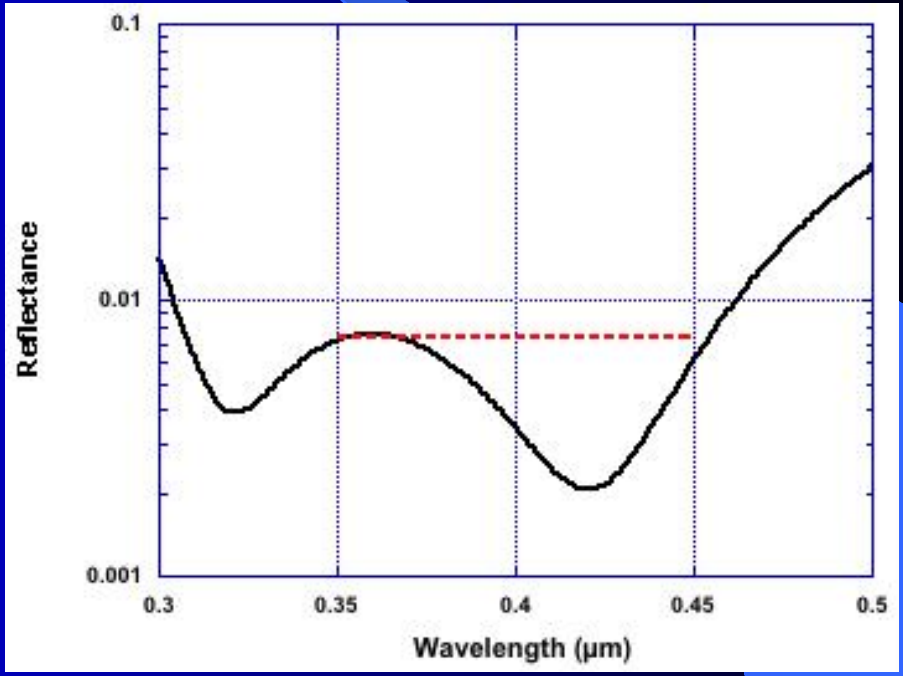
New System

Anti-Reflective Coating Model

SiO_2, AlN, and ZrO_2

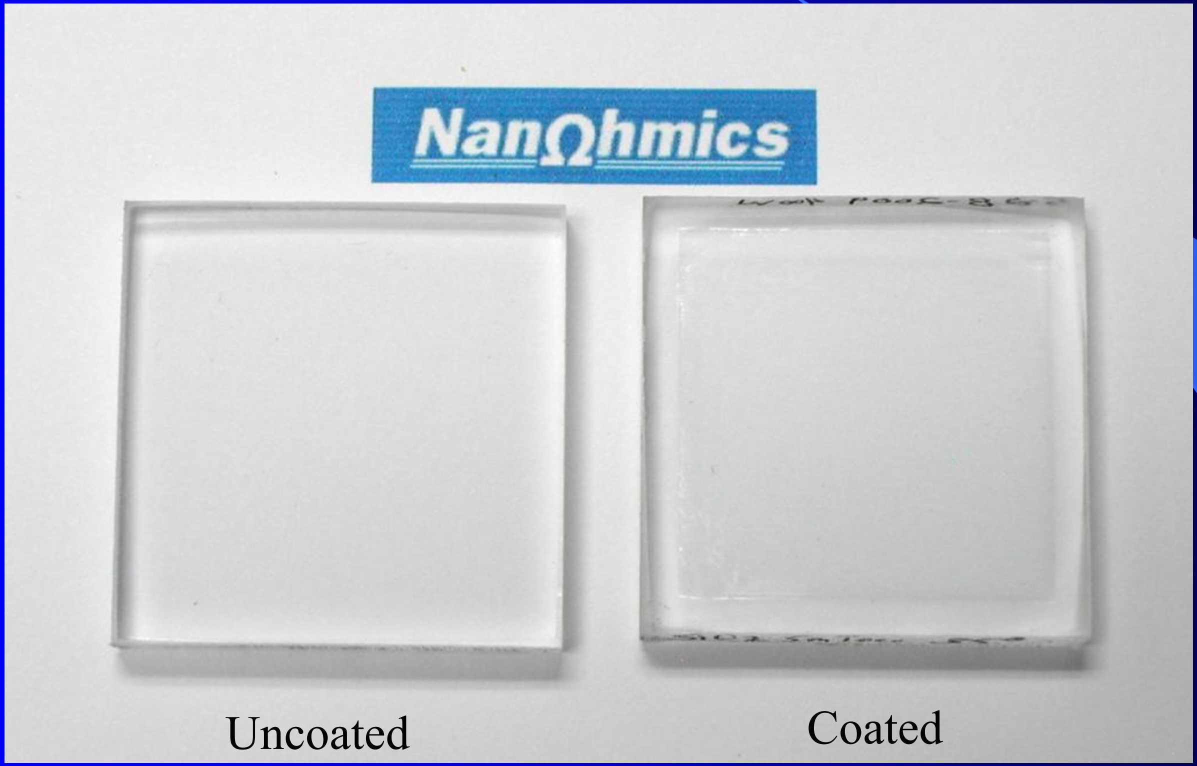


Prescription

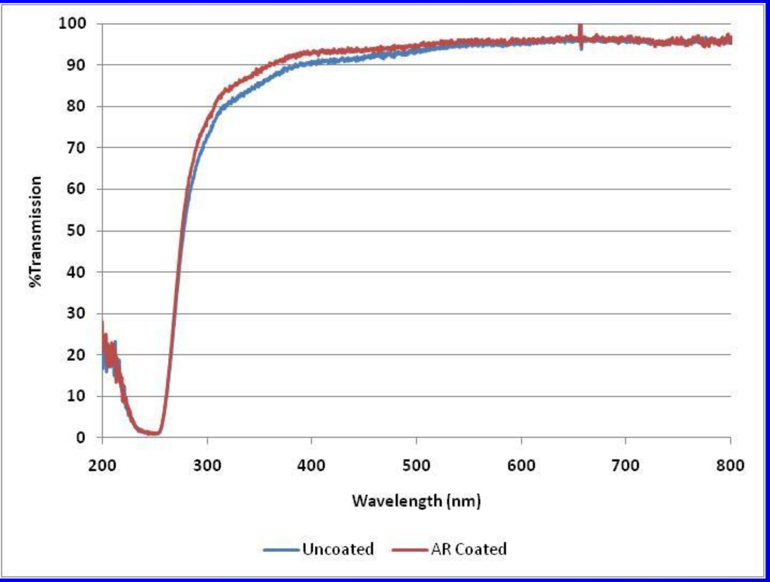


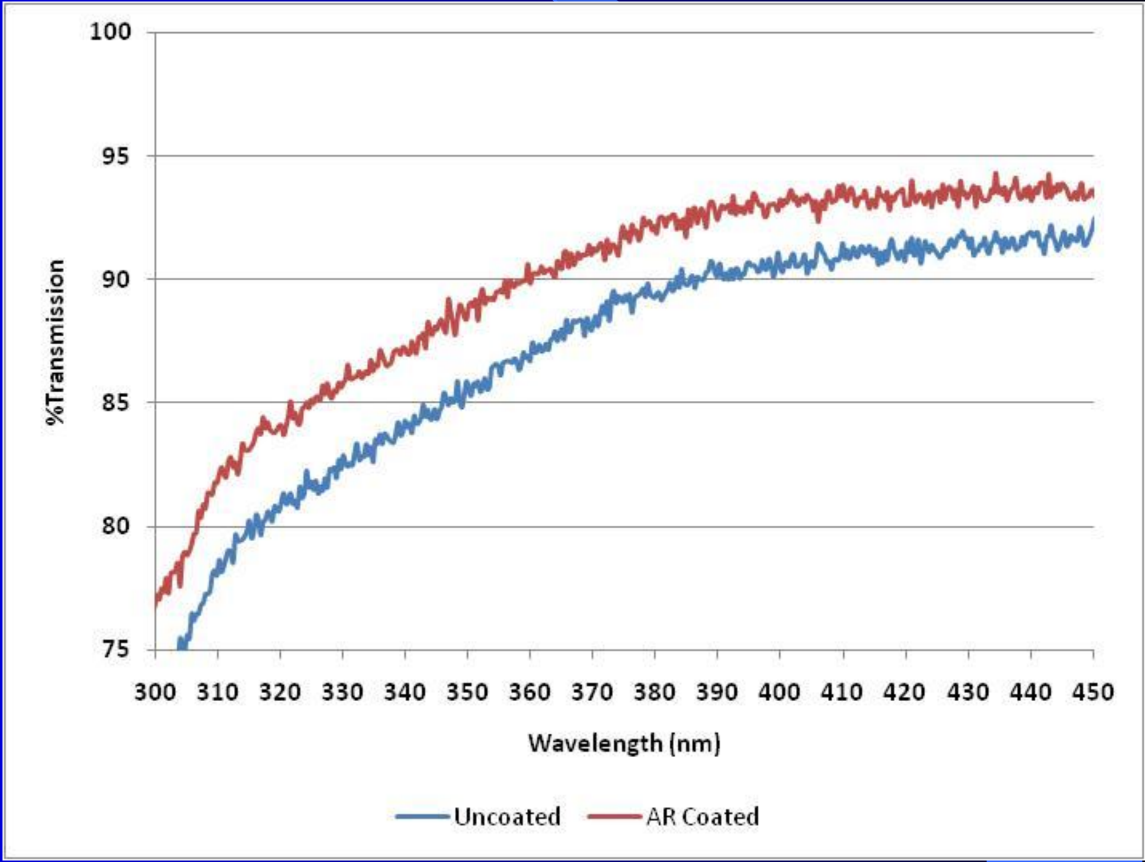
Anticipated Spectrum

AR Coated UVT PMMA



AR Coated UVT PMMA





Current Status / Results

- Designed and implemented new deposition
- Measured n and k for amorphous materials
- Stress eliminated in the films
- Initial AR coatings look promising

Future Work

- Improve models with new data
- Qualify new deposition tool
  - Deposition parameters
  - Coating uniformity (now at 90% uniformity)
- Deposition on Fresnel lenses
- Environmental Testing
  - Humidity
  - Temperature cycling
  - UV exposure

Small
Business
Innovation
Research

Multilayer Anti-Reflective Coating Development For PMMA Fresnel Lenses

Nanohmics, Inc.
Austin, TX

INNOVATION

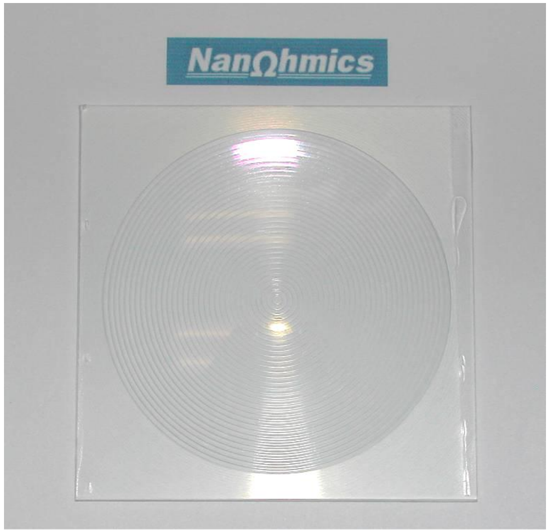
Nanohmics is developing a robust, radiation-hard, anti-reflective coating for use on polymeric Fresnel lenses.

ACCOMPLISHMENTS

- Novel deposition system designed , fabricated, and implemented
- Low stress, high quality dielectric materials deposited on a variety of substrates including polymethylmethacrylate (PMMA)
- Highly amorphous films achieved
- Excellent adhesion to most materials
- 90% uniformity achieved

COMMERCIALIZATION

- Primary markets for the coatings include optics, tooling, and ceramics.
- Presently using the technology to increase the strength of ceramic drilling materials.
- Sales from the technology have reached $12,500. If successful, a revenue stream of 2% gross is expected from our partner.
- Exploring partnerships with optics manufacturers.



AR Coated PMMA Fresnel Lens

GOVERNMENT/SCIENCE APPLICATIONS

- Technology being developed for use in the Extreme Universe Space Observatory (EUSO).
- Coatings still must be fully tested.
- Technology can be used for any number of robust , hard coatings especially for optical materials.
- Polymeric lenses will result in a lower launch weight and enhanced savings over using glass lenses.

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